Comparative study of Hydroponic and Geoponic Systems

By

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(with specialization in Water Resource Engineering & Management)

DEPARTMENT OF CIVIL ENGINEERING
CAPITAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
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A research thesis submitted to the Department of Civil Engineering,
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CERTIFICATE OF APPROVAL

COMPARATIVE STUDY OF HYDROPONIC AND GEOPONIC SYSTEMS

BY

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DEDICATION

Dedicated to

Professor Arshad Qureshi

(My father)

A strong yet gentle soul, who has taught me to believe in hard work and honest living- Abu you, will always be missed

ACKNOWLEDGEMENT

Praise be to Allah for every blessing. And I ask Allah for every virtue. And seek refuge in Allah for every vice. And seek forgiveness from Allah for every sin.

(Surah-Bani Israil. 80)

First and foremost, I would like to express my heartfelt acknowledgment and thanks to Almighty Allah for his blessing in completion of my work Alhamdulillah. I thank the Holy Prophet Hazrat Muhammad (S.A.W), the messenger of Allah for his guidance to walk in the right direction following Islam.

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I have no words to acknowledge the efforts of my mother and my all family membersin fulfilling my targets. Their love and care has always been unconditional and beyond any limit.

I like to express my profound appreciation to my wife and my daughter for their love and support. JazakAllah khair.

Muhammad Umar Nadeem Qureshi
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LIST OF ABBREVIATIONS

AHF	Abbottabad Hydroponic Farm
S.D	Standard Deviation
C	Carbon
H	Hydrogen
O	Oxygen
N	Nitrogen
S	Sulfur
K	potassium
Mg	Magnesium
Ca	Calcium
Cl	Chloride
Co	Cobalt
Fe	Iron
Mn	Manganese
Mo	Molybdenum
Zn	Zinc
G.I	Galvanized Iron
L	liter
Kg	kilogram
y	year
Sqm	Square meter
PH	Potential of Hydrogen

ABSTRACT

There is a rising attraction in hydroponics because it can be used in non-conventional locations like inside warehouses, marginal lands and water scarce areas. The water use of hydroponic production has been collated with of geoponic production with the example of tomato production in the northern part of Pakistan.The geoponic data are obtained from the field adjacent to the hydroponic farm house Abbottabad.The geoponic data has been equated with hydroponic data of tomato production obtainedby adopting the engineering equations and compared with literature values. Yields of tomato in a greenhouse unit with size of (2950 ± 100sqm) having 7500 plants of 12.5 ± 0.5 kg/sqm/crop have water demands of 5.41 ± 0.55 L/kg/crop (±S.D). When compared with geoponic production,the yieldobserved1.04 ± 0.06 kg/sqm/cropfor water demands of 449.48 ± 89.89 L/kg/y. Hydroponics offered 83.08 ± 8.25 L/Kg/crop times less water requirement with 11.80 ± 0.26 kg/sqm/crop times higher yields compared to geoponically produced tomato. To the authorsô apprehension, it is the first quantifiable comparison of geoponic and hydroponic production with the example of tomato grown in northern Pakistan. The construction of hydroponicsheds system requires hard work, and care and initial investments.It is recommended that this system can be selected as a step to produce the food crops to meet the exhaustive demands and to handle the water scarcity particularly in attractive regions for hydroponic farming.

LIST OF INTENDED PUBLICATIONS

Intended journal article

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CHAPTER 1

INTRODUCTION

1.1 General

The word 'Hydroponics' was invented by Dr. W.F. Gericke in 1936 to narrate thegrowing of plants with water solution along dissolved nutrients. The word ǒhydroô means water whereas óponosô means labour (Murali 2011). The term geoponics refers to growing plants in normal soil. So there is no inert medium in hydroponics system. It has likewise been noted in some states of the world that plants do not develop in the natural available soil.

Hydroponics is a technology of developing plants in nutrient mixture (nutrients plus water) and by using or without using any medium (e.g.,Sand, crushed stones, wool, coco fiber) to offer supportive reinforcement.In the world, all hydroponic systems are surrounded in closed shed structure to hold and moderate temperature, reduce evaporation, disease and infestations of pest.There are significantbenefits of hydroponic system in controlled environment.These are, effective usage of water and plant foods, minimal usage of land area and high-density crop yield.Moreover,production of crop where no satisfactory soil exists, not adequate temperature and seasonality indifference, mechanized suitability, disease and plague control.The advantage of hydroponic system as compared to geoponic grown products is the shutdown of the bunch of the filth, which oftentimes has problems of drainage, salinity, pests and diseases.

The reason to develop hydroponics is the need of growing edible plants in water scarced and unsuitable areas. The use of environment friendly controlled environments can overcome cultivation difficulties. Hydroponic system is more beneficial as compared to geoponicone because this system does not promote the use of pesticides and chemicals fertilizers. More production can be achieved with the lesser quantity of water throughout the year by using hydroponic technology.

Agriculture faces new challenge due to both population increase as well as the requirements of getting healthier, high quality vegetables with minimal usage of pesticides. Hydroponics, the science of growing plants without soil, has a great potential to fulfill these needs. Hydroponic will reduce use of inputs and will reduce contamination of our environment and natural resources. Substrate based growing systemlike coco-fibers and rock wool materials are very effective for crops like tomatoes, capsicum and cucumber. These materials are successfully used for intensive production of tall crops. This technology is widely used worldwide and it has been subject of extensive research in many places with minimum adaptations. Growing gutters can be successfully implemented in Greenhouse systems for vine crops.

A controlled environment/ structure to create green house for hydroponic is shown in figure 1.1. The structure is mainly built with G.I pipes and is covered with polyethylene sheet. Figure 1.2 represents the layout of irrigation system inside the hydroponic greenhouse to supply the nutrient mix water solution to the plants.

Figure 1.1: Hydroponic greenhouse structure

Figure 1.2: Hydroponic irrigation system

1.2 Research motivation

Water acts as a pivotal part in the economic system of a nation.The water resources in Pakistan are depleting day by day.The agriculture sector and public health are affected by the quantity as well as quality of water. Population growth, rapid industrialization and urbanization cost impact on water demands.It is therefore necessary to promote those technologies which are more favourable for water scarce regions. The motivation behind this research is to utilize and improve the economic utilization of water resources in water scarcity.

1.3 Research objectives

The overall aim of the research program is to utilise and improve the economic utilisation of water resources in unconventional locations e.g. inside warehouse, marginal lands unsuitable soil areas and water scarce areas.

To the authorsô best understanding, itis the first quantifiable water usage comparison of geoponically and hydroponically grown tomatoes crop in Pakistan.

The specific goal of the research program is to conduct a study for comparison of water usage along with production yield for tomato crop in hydroponic and geoponic systems.The objectives are achieved by performing the tasks which are mentioned in section 1.4.

1.4 Research methodology

The water demand for tomato production in hydroponic system has been considered and is compared with geoponic system. The hydroponic data are obtained from Abbottabad hydroponic farm house Abbottabad whereas the geoponic data are obtained from the tomato field near Abbottabad and compared with the data of Pakistan Agriculture Research Council and Provincial Agricultural Research Departments. Both the data from hydroponic system and geoponic system are compared by applying on an area of 2950 + 100 sqm. Their comparison of water usage and fruit yield has been evaluated. The criteria for assessment and comparison of both the systems have been set through detailed calculations. As the hydroponics system is not commonly used in Pakistan, its impact on agriculture, water resource, and environmenthave been discussed. Moreover, recommendations have been provided for the adaptation of the system.The research has been carried out by collecting the following data.

ÅData collection of tomato crop from Abbottabad hydroponic farm.

ÅData collection for geoponic system from adjacent field of Abbottabad hydroponic farm.

ÅComparison of water demand in both the systems

ÅComparison of tomato yield in both the systems

ÅConclusion and recommendation for future

1.5 Thesis layout

The thesis layout comprises of six chapters. These are:

Chapter 1 consists of introduction. It explains about the background of hydroponics and geoponics, research motivation, research objective and methodology, and thesis layout.

Chapter 2 contains literature review. It consists of background, behavior of hydroponics and geoponics, some previous researches on hydroponics and geoponics,introduction about tomato along with botanical classifications.

Chapter 3 Information about the locations and ware about of the study area followed by research methodology.

Chapter 4 explains the material and methods involved on the setting up of hydroponics system more over procedure of growing tomatoes through and details of equipments used in the hydroponics system.

Chapter 5 gives of results and analysis regarding the water usage and production oftomatoesthrough hydroponic and geoponic systems.

Chapter 6 outlines conclusion and recommendations.

References

Annexure

CHAPTER 2

LITERATURE REVIEW

2.1 Some researches on hydroponicand geoponic systems

Hydroponic greenhouses arrived in England and France in the 17th century; in 1699, Woodward grew hydroponic mint plants in England. Hydroponic Greenhouse has significantly grown in Europe and Asia during the 1950s to 1960s, moreover large hydroponic systems have matured in the deserts of California, Arizona, Abu Dhabi, and Iran in 1970 (Fontes, 1973; Jensen and Teran, 1971).

The main principles involved to supply nutrient mixture to the plants are the use of irrigation system that consists of pipes and sprays controlled by hydroponic controllers. At about 1860 the fundamental laboratory procedures of nutrient mix solutions were solely formedby Knap and Sachs in Germany (Hoagland and Arnon, 1938).

Gericke instigate the term hydroponics in 1937 (although he asserts that the term was suggested by Dr. W. A. Satchell, of the University of California) for the cultivation of plants in water (from the Greek hydros, "water", and pianos, "labour") (Douglas, James. 1975). In 1978, hydroponics pioneer Dr. Howard Resh published the first version of his book "Hydroponics Food Production."

The main principles involved to supply nutrient mixture to the plants are the use of irrigation system that consists of pipes and sprays controlled by hydroponic controllers. At about 1860 the fundamental laboratory procedures of nutrient mix solutions were solely formed by Knap and Sachs in Germany (Hoagland and Arnon, 1938). This interest began to develop in the possible use of complete nutrient solutions for commercial scale crop productionin the United States, at about 1925 (Withrow and Withrow, 1948).

Hydroponics is a skill of plants growing in a soil less medium. The plant roots take feed from the rich nutrient mixture which consists of all important elements which are very important for the development of a normal plant. The hydroponically grown plants are not organically different than the plants raised in normal soil. The organic and inorganic constituents require to be broken down into inorganic components to feed the plant in hydroponic system of growing. (Carpenter, 1994).

Even so the procedure of acquiring the minerals from the soil in geoponic system is different as compare to hydroponic system. Mineral nutrients become available for plant use when soil colloids release minerals into the dirt particles through solubilization of soil minerals and organic matter (Resh, 1995).

In hydroponic cultivation, dissolved nutrients are given up to the plant right away without absorbing into soil. Therefore, hydroponics allows the growing of plant by maintain the most appropriate nutrient state. Nevertheless, the allowance of error is large due to the lack of absorption capability, which can result in plant undernourishment. Hydroponics is an efficient, profitable, and sanitary technology for raising plants. Hydroponics is a valuable way of developing plants in areas with little arable land or regions with heavy, dense populations Hydroponic growing system fulfills the need for locally grown organically produced fruits and vegetables during the off-season. Hydroponic culture allows for gains in density spacing and yields due to minimal competition among the radicals. For example, hydroponic organic basil production in California spaced their plants at 12.7 cm. Hydroponic grown cultivation has the capability to minimize the disease and pest problems.(Schoenstein, 1996).

Plants grown hydroponically have three times increase in vitamins and minerals compared to plants raised in dirt. (Skagg, 1996)

By increasing the awareness among the people regarding the hydroponic growing system technology, it becomes the ideal technology to save the natural resources e.g. water. The production of vegetables and fruits of the hydroponic system have rich value, moreover it consumes less water about 10 to 30 times. Hydroponic technology plays a vital part in developing regions having water scarcity, less arable land area, environmental issues and problem of food security. Holding in view the shortage of water in the state, the hydroponic system which consumes less water shall be the need of the time to come. This can be set up in the backyard, moreover on the roof garden of the mansion. In the urban environment with limited water resources hydroponics system can be used as the best way to earn a livelihood by continued growth of organic fruits, vegetables and flowers on any scale having the local environment (B. A. Sheikh, 2006).

The roots of plants are hanging on a reservoir of nutrient mixture or inside a conduit connected to the reservoir. The Plants become grow under optimum conditions like nutrient mixture, temperature, aeration, and pH. In this technique oxygen is determined into the nutrient mixture, leaving the roots to absorb nutrients mixture quickly and more efficiently. This facilitates stimulating the rapid evolution, stop algae formation and consequences in high yields (Lakkireddy 2012).

Geoponic system is facing some major challenges with the increase of population and land use issues all over the world. Due to rapid industrialization and urbanization, threats from climate change and its related effects, cultivation of land is facing challenging threats like water logging, salinity, land use area and water scarcity.

Under such circumstances, in the future, it will become difficult and unfeasible to feed the entire population using the production from conventional/geoponic system (Aatif et al. 2014).

There have been a few studies on commercial scale of Aquaponics production. The objective of those researches was to study the methods of crop production, land use area, water usage requirements, profitability and yields (David 2014).

Anextensive range of negative effects on the environment is caused by the geoponic production. Geoponical production has been traditionally defined as growing crops in natural soil by using different pesticides and herbicides with irrigation water in open air. The undesirable impact of geoponically produced agriculture includes a larger land requirement and inefficient use of water Hydroponics system gives 11 ± 1.7 times more yields, required 82 ± 11 times more energy as compared to geoponically grown lettuce (Guilherme et al. 2015).

The hydroponically growing fruits compared with geoponically havea lot of environmental advantages and can be an alternative of supportable food production in non-arable areas of the world. The research on hydroponically grown raspberries investigated the likely, undetermined sensory differences, and ascorbic acid compared to geoponic raspberries. Sensory evaluation results by inexperienced participantsinterpret that they were impotent to differentiate between hydroponic and geoponic raspberries. Sensory evaluation shows that most of the participants (87%) could identify difference between hydroponically and geoponically grown strawberries and 70% liked the hydroponically grown strawberry (Chenin 2015).

Thither is a rising interest in Aquaponics (second name of hydroponic) because it can be used in non-traditional locations for agriculture, such every bit inside the warehouse, on marginal lands and can offer locally grown products without using synthetic pesticides and chemical fertilizers (David et al. 2015).

2.2 Brief of hydroponicTomato Plant

The tomato also called the honey apple, generally sprawling plant in the nightshade family cultivated for its consumable fruit. Savoury in flavour, the fruit of different varieties ripens to a typical red coloration. The height of tomato plants typically reach to 3ï 10 ft (1ï 3 meters) and have a light roots that creeps over other plants. The tomato plant leaves are approximately 10ï 25 centimetres (4ï 10 in) in length, the size of leaflet becomes 8 centimetres (3 in) long, with a saw edge margin. The leaves and stems of the tomato plants are very thick hairy.

The flowers are 0.4ï 0.8 in (1ï 2 centimeters) across, having yellow colour, with five pointôs nodes on the corolla. The blooms are held together in a cyme of 3ï 11. This is perennial, in temperate climates these often grown outdoors as an annual.The maturing time of a crop in hydroponic system is 3 months, whereas in geoponic system growing time of a crop is 4 months. Fig 2.1 shows the closed environment hydroponic farm house of tomato along with the heating arrangements in summer season to keep the environment controlled for continuous production.

Fig: 2.1 Heating arrangement in hydroponic sheds

Unspecified breeds of tomatoes are also labeled as ñVining" tomatoes. Their growthand fruit production continue until they gain heights of up to 10 feet, whereas 6 feet height are considered the normal or damaged bythe frost action. The plant gives flowers; gives new fruit, ripe fruit and this took place at the same time throughout the harvest season.

The yield and consumption of tomatoes expanded rapidly in the USA in the 19^{th}century, and by the close of that century processed products such as soups, sauces and ketchup were regularly consumed (Harvey et al., 2002). Determinate varieties of tomatoes, also called "bush" tomatoes, are varieties that are bred to boost to a compact height (approx. 4.5 feet). The growing of plants further stops when fruit comes at top bud or at end, ripen the entire crop at or about the same time (usually over a 2-week period), and then go out.

2.3 Botanical Classification of Tomato

Table 2.1: The table shows the botanical classifications of tomato plant*

Kingdom	Plantae
Class	Eudicots
Phylum	Angiosperms
Genus	*Lycopersicon*
Species	*Esculantum*
Family	Solanacae

*(Ref:ñslow food upstate from renatovicario.com/pdf/tomato.pdf)

2.4 Origin of Tomato

Tomato fruitclassified as the genus Lycopersicon, and Lycopersicon esculantum is developed for its edible fruit. The genus Lycopersicon of the family Solanacae is considered to have originated in the coastal strip of western South America from the equator to about latitude 30° south.These cases of tomato initially belong to South America, especially Galapagos Islands and Peru, been first trained in Mexico.In the middle of 16th century, the tomato brought out in Europe, primarily featured in early herbals.It was farmed for the peach of its yield, but was not often eaten, except in Spain and Italy.The tomato was thought to be poisonous, particularly its relative, and the deadly sharp sweet taste.All related wild species of tomato are originally from the Andean region that includes regions of Ecuador, Bolivia, Chile, Colombia, and Peru (Sims, 1980). The most likely ancestor is the wild L. esculantum var. cerasiforme (cherry tomato), which is native throughout tropical and subtropical America (Siemonsma, 1993). Although the ancestral forms of tomato grew in the Peruï Ecuador area, the first extensive domestication seems to have taken place in Mexico (Harvey et al., 2002).

In the early 16th century Spanish introduced tomato into Europe (Harvey et al, 2002). The acceptance ofthe tomato as a cultivated crop and its addition in the food were relatively dull in the European.It was initially introducedas fancy plants. The fruits were considered to be toxic, because of the closely related deadly nightshade (Solanum dulcamara).Since the mid-16th century tomatoes have been worked and eaten in southern Europe, though they only became widespread in northwestern Europe by the remainder of the 18th century (Harvey et al., 2002).

Fig 2.2 shows the tomato plants ready for transplantation to the growing gutter in hydroponics farm.

Figure 2.2:Tomato plant in hydroponic system

2.5 Nutrients in Tomato

Tomatoes have been recognized to comprise of an act of significant nutrients and are believed to agree a number of nutritional benefits to their users. Infect, tomatoes are said to decrease the risk of a number of fatal disease, like cancer and heart attack. The tomato has been known to consist of the following nutrients vitamin K, vitamin C, vitamin A, fiber, sugar, potassium, iron, lycopene (an Antioxidant) and some amounts ofPotassium, Phosphorus, and Sulphur.

Tomatoes have also been associated with low content of calories, fats and sodium. The presence of antioxidants in tomatoes is said to be helpful in cleansing the body, of toxic compounds. Lycopene, present in tomatoes, has been known to neutralize free radicals and reduce the danger of prostate cancer.Those who eat raw tomatoes have been found to suffer a lot less hazard of developing rectal, colon and stomach cancer. It is believed that tomatoes block the effects of nitrosamines and thus, cut down the risk of lung malignant neoplastic disease. Researches have indicated that eating tomatoes might help cut the danger of heart attack. The vitamin K present in tomatoes helps in maintaining the bones strong and healthy.

In the 17th century, Europeans adopted the tomato in China, South and Southeast Asia, and in the 18th century in Japan and the USA (Siemonsma and Piluek, 1993).

In Pakistan tomato is grown on an area of 40238 ha with annual productions of 566043 tones as given in Table 2.2 below (Fruits, Vegetables and Condiments Statistics of Pakistan, 2014-2015.)

Table 2.2: the table shows list of top 10 countries of Import of tomato

Position	**Country**	**Production of Tomato (Kgs)**
1	Afghanistan	31,512,115
2	Bahamas	27,990
3	Iceland	31,822
4	India	190,450,954
5	Indonesia	17,000
6	Iran	1,261,050

7	Iran	4,781,018
8	U.S. America	16,350
9	United Arab Emirates	32,690
10	United Kingdom	110

2.6 Why Tomato Crop

Although there are a list of fruits, vegetables and flowers which are practiced to grow through hydroponic technology. Fundamentally, the selection of tomato crop is based on the availability of hydroponic system along with the available crop in the sheds. Moreover, it is based on the need of the population of the country.Abbottabad hydroponic farm hasthe facility of hydroponic strawberry, capsicum and tomatoes. Whereas at the time of explore the available hydroponic and geoponic crop in the same vicinity was tomato. Tomato is a crop which is widely used for cooking.

CHAPTER 3

DATA COLLECTION AND RESEARCH METHODOLOGY

3.1 Study Area

The study area is located in Bilal town, Abbottabad at easting 73° 14ô E, northing 34° 10ôN, and elevation of 1192 m above sea level. Location of study area is shown in the fig 3.1.

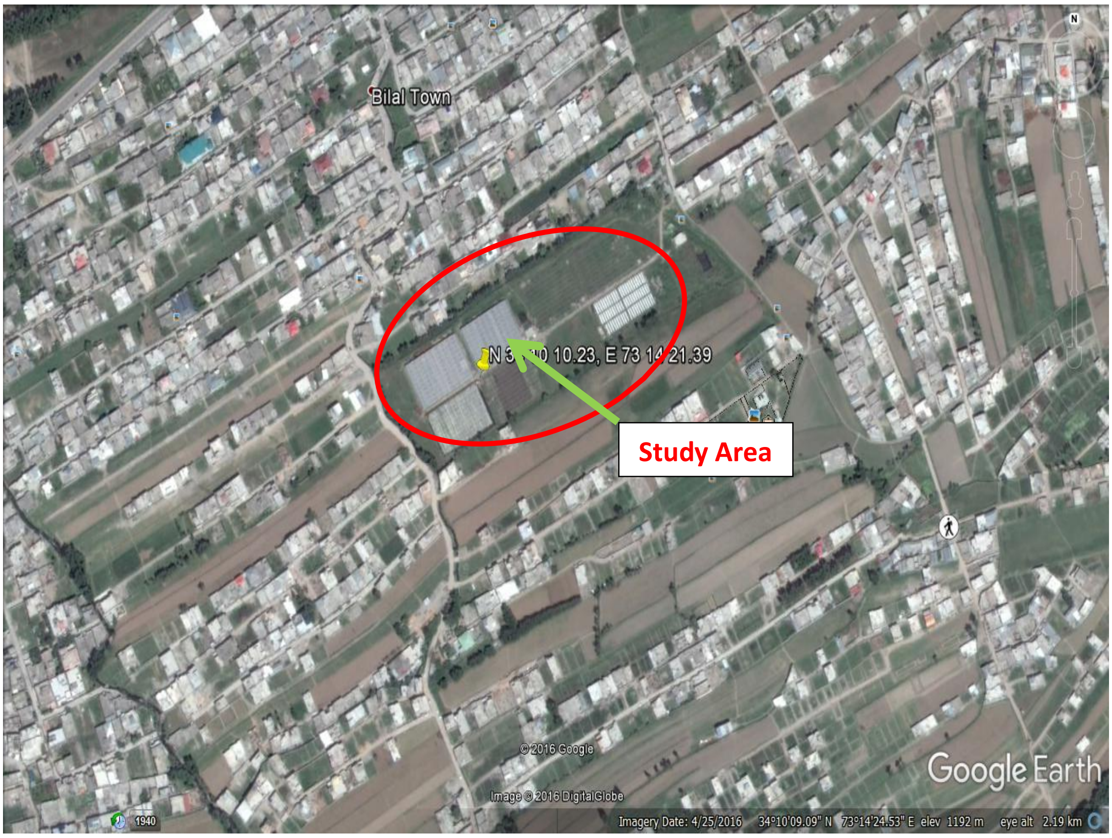

Fig 3.1: Study Area for hydroponic. (Picture taken from Google earth)

The Hydroponic farm is accessible at a distance of 5km from Karakoram highway on Kakul road. The study area is easily accessible from existing metaled road. The Project exists in a Populated area. Abbottabad hydroponic farm is surrounded by houses from north, east and west side whereas by south side there are mostly fields.

3.2 Climate

The task area has maximum temperature 30°C maximum and minimum temperature -1°C.The average annual temperature in Abbottabad is 18°C. The average annual rainfall is 1262 mm. The land is suited for almost all types of vegetables.

3.3 Description of study area

The farm house has an overall area of 15 Acres. It is owned by Mr. Waqas khan who permitted periodic study for the tomato crop. This farm accommodates 4 no of Greenhouse sheds which accommodate fruits and vegetables. The tomato crop was harvested only in one greenhouse shed of 220 ft x 146 ft (about 0.74 acres) in which 7500 plants are grown (Refer fig.3.2).The geoponic farm area selected for the study purpose consists of about 0.75 acres in which about 7500 plants are grown (Refer fig.3.2).

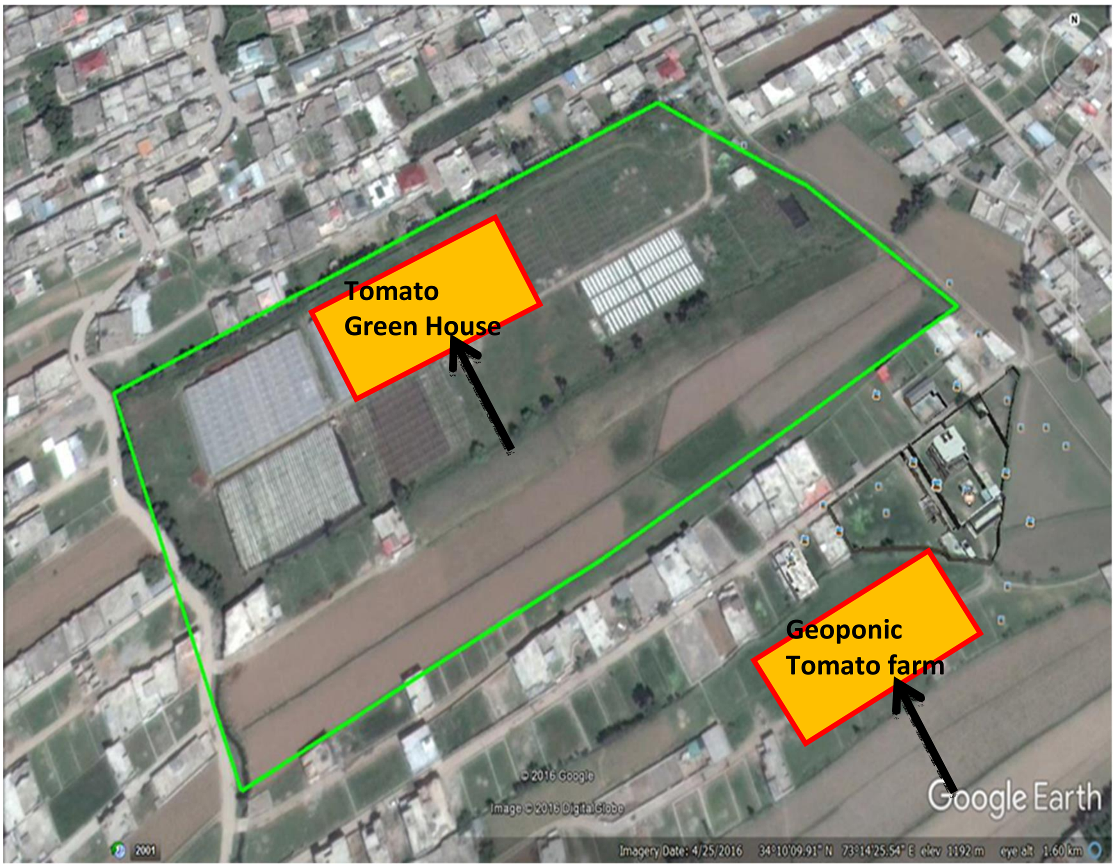

Fig 3.2: Greenhouse shed and farm area for tomato crop (Picture taken from Google earth)

The tomato crop is a short-lived perennial, and can be retained for periods of a year or more in favourable environments.

3.4 Data Collection

Hydroponic system, water utilization and output data, in terms of water usage and yield, from Nov 2016 to Feb 2017 has been observed from the Abbottabad Hydroponic Farm for the winter season crop of tomato.The size of greenhouse shed at AHFis 220ft x146ft having an area of 2950±100 sqm (± is the standard deviation).

The greenhouse shed facilitates 7500 no of tomato plants. The total crop period for hydroponic system is 3 months.Geoponic system water usage and output data from November 30, 2016 to March 01, 2017 has been observed from the fields in the vicinity of the Abbottabad district for the 1 acre area and rationalized with the field of hydroponic system shed.After the collection of data, the water demand and yield for both the systems hasbeen compared. The crop period for geoponic system is 4 months.

3.5 Methodology

Water pattern for hydroponic and geoponic system from sowing to harvesting stage of the tomato crop has been observed and is converted to the comparable units with regard to the time period of single crops. The yield of tomato has been observed with respect to the water usage for both the systems.

3.6 Data Analysis

3.6.1 Hydroponics

Hydroponic system water demand data has been studied from the transplantation of plant from nursery to Growing gutter in the shed. The water calculation has been made starting from first stage watering @ 1 liter per plant / day. This water supplied at once to the plant. After the first watering, the next stage watering is for 45 day which is called blossom stage during which the water requirement is 200-300ml/day/plant. Then there is third stage of watering which is for 15 days and is called fruiting stage. The requirement of water at that stage is 300ml/plant/day. The final stage is called harvesting stage with a period of 30 days and water requirement at that stage is also 300ml/plant /day. The total water usage for 7500 plants has been calculated along with the yield of tomato for this crop and a relationship between water usage and yield has been developed for the single crop. The noted yield of Abbottabad hydroponic farm of tomato is 35 to 37.5 tones with 7500 plants.

3.6.2 Geoponics

Geoponic system water demand data have been studied from sowing to harvesting stage of the tomato crop in the adjacent farm of Abbottabad hydroponic green house. The location of geoponic farm is shown in fig 3.3. The soil preparation time in the geoponic field is 10-15 days.As the area studied for geoponic system was in acreswith 10,000 plants/ acres. This domain has been justified with the hydroponic area to have most appropriate comparison.The water calculationshave been observed starting from sowing stage watering to harvesting stages that is generally measured with reference to the depth of water which are 400mm to 600mm / plant / crop. Total 16 numbers of watering have been observed and is equally distributed in 14 to 16 weeks. One watering in a week is 25mm to 37.5mm /plant / week. The total water usage for 7500 plants has been calculated along with the yield of tomato for this crop and a relationship between water usage and yield has been developed for the comparison. Whereas the average production in geoponic system is 4 to 4.5 tons/ acre.

Fig 3.3: Study Area. for Geoponic (Picture taken from Google earth)

CHAPTER 4

MATERIAL AND METHODS

4.1 Background

In Abbottabad hydroponics farm tomatoes are naturally grown in weather-controlled greenhouse sheds. This indoor production allows for year-round production of tomatoes that have a superior taste, high brix content.Vine tomato is a very low calorie with high water and mineral contents.

4.2 Resources at AHF

Resources available at Abbottabad Hydroponic farm are followings.

(i) Head House: It is a central control room. All greenhouses are connected to it.

(ii) Irrigation room: In irrigation room there are recipe tanks, with booster pump.

(iii) Storage water tanks: these tanks store water coming from well.

(iv) Packing area: in this area packing of harvested product is done.

(v) Well water: The available source of water is well water.

4.3 Cooling

It is achieved by pad wall and fan cooling system which consists of Pad wall, Circulation fans, and Exhaust fans. It is the best way to reduce the temperature. The exhaust fans throw air out at one end and drag moist air at the other end. Water is provided at one end on the pads which are opposite tothe mounted fans bypiping system that sprinkles the wateronthe porous material (synthetic fiber) called cooling pads.Theair comes in through the wet fiber pads.The water dropped by the fiber pads collect in achannel, at the tail end, which drains out into a collection chamber. This is part of procedure but it is not applied for this study as it is carried out in Nov to Feb

4.4 Operation of AHF

The whole operation is going through different sorts of machinery. In this machinery, following are the components:

1) Irrigation unit.

2) Filtration unit.

3) Heating unit.

4) Cooling system.

The water coming from water source goes to filtration unit which purify the water.This water goes to irrigation unit from which it is available to all plants. Cooling is achieved by pad wall and fan system which consists of, Pad wall, Circulation fans, and Exhaust fans. The exhaust fans throw air out at one end and drag moist air at the other end. Waterdelivered at oppositeend of the fans whichsupply the water to pads which areporous material (synthetic fiber) called cooling pads. The air comes in the greenhousethrough thesefiber pads.The water dropped outby the pads is collected through a channel, at down site of the pads, which drains the water into achamber. The fertilizer used in Abbottabad hydroponic farm, mixed in two tanks ñAò and ñBò. In A tank macronutrients are solved and in B micronutrients are solved.

In fertilizer macro nutrients are Calcium nitrate, Calcium chloride, Potassium nitrate, Potassium sulphate, Mono potassium phosphate, Potassium chloride, Magnesium sulphate and Micronutrients are Zinc sulphate, Borax, Nitric acid, Copper sulphate, Sodium moly date, Iron chelated, Manganese sulphate, phosphoric acid.

The essential elements of nutrients are mentioned in the Table 4.1 along with their relevant functions for the tomato plant growth.

Table 4.1: Essential elements and their function in tomato plants

Essential elements	**Functions in plant**
H, S, N, O, C	The enzyme process assimilation through oxidation response depends on the important components of atomic groups. These are the major parts of the nutrition.
P, B	Esterification process with native alcohol groups. In energy transfer the phosphate esters process involved

Ca, Mg, K, Cl	Osmotic potentialsdevelop due to nonspecific functions. The specific responses in which the ion brings about the optimal shape of an protein enzyme which connect the reaction partners, balanced anions, controls permeability of membrane and electro potentials
Mn, Zn, Co, Mo, Fe	Presently in a chelated form which incorporated into a prosthetic group that enablesvalence changes due to the transportation of electron.

4.4.1 Cultivars

Tomato cultivars used in Abbottabad hydroponics are beef tomato.

4.4.2 Tomato growth stages:

Table 4.2 *the table shows all the stages for the growth of tomato plant in hydroponic system*

Table 4.2: Stages of tomato growth in Hydroponic system

Stages	**Duration**
Germination	4-5 days
Transplanting	12-15 days
1st flower cluster	6-8 weeks after sowing
Additional Clusters	Every 7-10 days after 1st cluster
Ready for Harvest	6-9 weeks after flowering

4.5 Sowing of seeds

Seedshaving good health, of specific variety andtreated vigorously have more than 80% germination. The seed should have been purchased from a viable source.Rock wool/coco substrate is used to sow the seed. This is a material which is made by spinning the lime stone, coke and volcanic rocks. Put the propagation plug in propagation trays. Sow the seeds within the tray up to 0.6-1 cm depth and place it in the greenhouse and cover with plastic sheet to retain under high humidity.Water them with nutrient solution.

4.6 Propagation through Suckers

A tomato plant has been propagated vegetative through suckers. The mark is cut from the plant, cut should be slanting one. Then rooting hormone is applied at the cut and this small plant is inserted in the rock wool block.

4.7 Transplanting

12-14 days after germination when true leaves appear, transplant the plants in growing blocks. Plants are shifted in rock wool blocks with propagation plug in which roots are penetrated. These blocks are kept in trays and dipped in nutrient solution. These blocks absorb the solution which is necessary for growth. When plants attain 15-20 cm height then these are shifted to coco slab. At slab, plants are provided with nutrient recipe. Train up the supports which are to be at least 3 m above the ground. Wires attached with the roof of string should be strong enough to bear hundreds of pounds weight. Figure 4.1 shows the plants after transplantation form the nursery to the sowing gutter.

Fig 4.1: Transplantation of Tomato Plant into growing Gutter.

4.8 Fertilizer

As no chemical fertilizers are used for the growth of plants in hydroponic system Nutrients are being used as fertilizer in water solution. Two types of nutrients supplied to the plants through separate mixing tanks. Macro nutrients are mixed with water in tank A, whereas micro nutrients are mixed in tank B.

The nutrient solution for tomatoes is generally made in two or three levels for the various stages of growth. But the macro nutrients changes, getting increasingly more focused as the crop matures.The micronutrients remain the same throughout the maturation cycle. Nitric or phosphoric acid is used to bring down the pH if necessary Table 4.3 shows all type of fertilizers (Nutrients) used in hydroponic system of tomato production.

Table 4.3: Types of Nutrients used in hydroponic system

S.No	Macro nutrients	Micro nutrients
1	Calcium Nitrate Ca $(NO_3)_2$Å4H_2O	Zinc Sulphate
2	Calcium Chloride ($CaCl_2$)	Boron
3	Potassium nitrate [KNO_3]	Manganese Sulphate
4	Magnesium Sulphate ($MnSO_4$Å4H_2O)	Copper Sulphate
5	Mono potassium phosphate (KH_2PO_4)	Sodium moly date
6	Potassium chloride (KCl)	Iron chelated
7	Potassium Sulphate (K_2SO_4)	Nitric acid

4.9 Maintenance of crop

4.9.1 Training of plants

Training of plats is originated by viewing that the horizontal branches carrymore fruit than the vertical one.Moreover the higher branches of the plants bear more fruit then the lower ones.Training is principally concerned to give and shape and frame of the plant. It regulates the plant outline and its branches framework. By training we can preserve the plant in a manageable condition and can throw out the branches in desirable direction and location.

For training of plants a support system is used. A horizontal wire runs parallel to the direction of the rows above the crop at height of 3 m. Strings are used to train the plants as shown in fig 4.2. These are attached to the wire. These can opened when necessary. At lower side these are clipped with plants. The plants when reached at height, it requires inclination and dropping which is called lowering. This is done by holding the string with left hand and loosens the knot on the rightside.By doing this way allow the plant to down and slides the string to the right. If not slide then there are chances of breakage of stem. Leaning is always done by the similarway. The plants gives shade to each otherὂs when some plantsdown to the right direction and some are on the leftdirection. All the plants are lowered atconstant heightto protect from the shadeson other. This arrangement is repeated every time when the plant attain the height over the wire.

Figure 4.2: Sting System for plant holding.

Curling the stem of plant around string is called twisting. Twisting is done for giving support to the plant to climb upward. Twisting is always done in the same direction, clockwise or anticlockwise. When the plants gets heavy fruit, the sting maybreak or slip down and so plastic clips are used to secure the plants to the string. In this way plant uses the vertical space. By clipping plant is kept attached with rope. Clipping is the process of tying the stem of plant with rope with the help of clip. Clipping is done to support and direct the plant in a particular direction. Clip attach to rope which is hanging. This rope is attached to a wire which is tied to walls horizontally.

4.9.2 Truss support (J hooks)

The shoot of the trusses are not strong enough tocarrythe heavyweight of fruit and getbent. The (J) hooks prevent the trusses from isolation due to heavy weight and maintains the fruits cluster from sharp bending.

Fig 4.3 shows the arrangement of the truss support along with J hooks. The support arrangement is carrying the load of plant and fruits and to keep the plant in a straight direction for moving of the staff inside the greenhouse more over to keep the whole operation manageable from growing to harvesting of the crop.

Figure 4.3: Tomato Plant support system

4.10 Pruning

Pruning is originated by the experience that the normal orientation of the plant branches in a specific posture is not adequate to make the crop, but a definite fruit exists in the plants towards the management of which sap flows as divert to the plant sticks out as abundantly and superior quality. As a matter of fact, itdetermines the capacity of the plant to produce fruit. Pruning has an effect on the portion of the plant as it influences cropping of plant highly.

This is done to remove extra load from the plantsand byisolating the shoots which are referred as ñsuckersò for the purpose to increase the size of fruit. The allowing of suckers on fruit plants to grow would increase the fruit intensity, but on the other side the quality and size of the fruits get compromised. It is more beneficial to have a main stem that carries fruit, as the production of fruits becomes of high quality and more uniform in shape and size. The problem of side shoot is that, it extracts the food as this is new plant. Due to this plant growth slows down because most of the food goes to the new plant and also fruit size doesnôt increase. To remove diseased, deformed and abnormal fruits, leaves, flowers etc, de-leafing is done for the removal of older leaves, sick leaves and damaged leaves. How much leaves should be removed depends upon the season. In summer larger number of leaves is kept at the plant to provide shade to fruit to increase its ripening time. In winter small numbers of leaves up to 10 leaves are kept at plant to provide sun light to the fruit for ripening as intensity of light is low in winter. By removing older leaves fertilizer wastage is decreased. Fertilizer goes to younger leaves and fruits. The main reason ofde-leafing is to increase the penetration of light in to the plantsand to maximize the circulation of air. Whole leaves are removed beneath the lowest fruit cluster, which has not been reaped. All the fruit which are undersize and small are removed at the end of each cluster. These under size fruits also affect the size of other fruit more over not desired in the market. In some of the cases, the onlyfruit leave which is near the plant and other all pruned in the cluster. The Pruning of the cluster depends upon the expected fruit size for the cultivar, the quantity of fruit normally form on the cluster, demanding size in the market and conditions of growing. The purpose of pruning is to maintain the size of fruit quality of the fruit and to balance load of the fruit. Basically pruning is done to keep the fruit sizeuniform. Flowerpruning is also done to improve the size and quality of fruit. Remove the extra flower of every cluster by leaving three or four flowers.

4.11 Topping

Before Six weeks from the crop termination date, the small fruit cluster at the tip of the plant becomes removed. An individual fruit requires 7-8 weeks from growing to harvest whereas the undersize fruit have not enough time to develop up tothematurity level. Topping has been done to enhance the development of fruit andto increase the size of the fruit at the lower part of the plant. Whereas, some of the leaves are leaved at the top of the plant to maintain the shad and to protect the fruits from direct sun effect.Leaving suckers and leaves at the top of the fruits increase transpiration, and reduce cracking of the fruit.

4.12 Pollination of tomato

The pollination of tomato flowers are through the wind. Whereas in the greenhouse the movement of air is restricted or less air movement, which is most required for the pollination process. Therefore, there are two options for the pollinatingof the tomato crop. These are mechanical pollination or to keep the hives of bumblebees in the greenhouse.

Mechanical pollination is done by shaking the flower clustersafter everysecond day when environmental conditions like humidity and temperature are excellent.

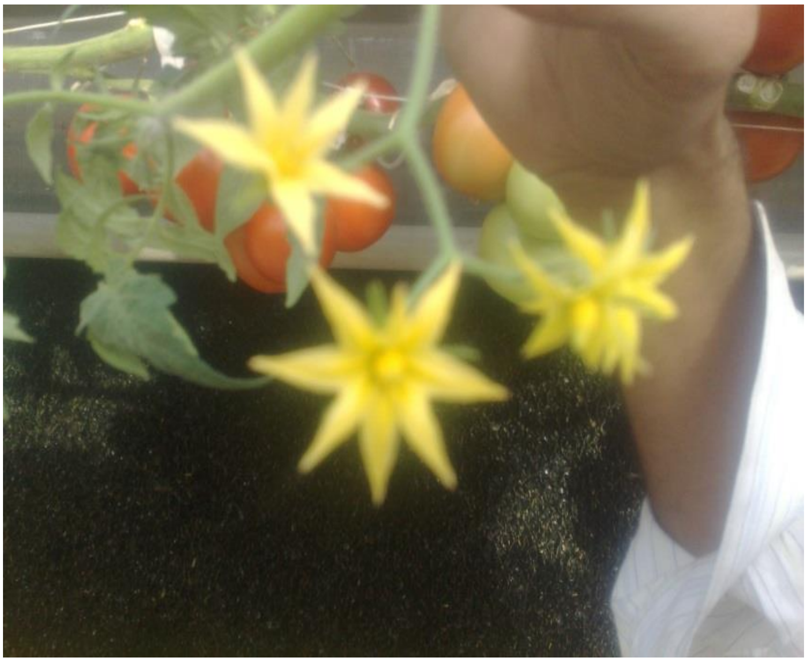

Figure 4.4: Flowering stage of tomato plants

Step 1

Purchased an electric pollination vibrator.

Step 2

Turned on the electric vibrator and touchit with the flowers of every cluster and plant. The process is used at each second day in-between 10.00 in the morning and 2.00 in the evening. This is the time whenthe levels of pollens are high.

Step 3

Kept the best surroundings in the tomato, green house. Humidity levels around 70 percent and temperatures below 85º F during the day time and above 65º F at night time is best suited for mechanical pollination.

Bumble bees are used for pollination. One hive works approximately one half acre (0.2hectare) of tomatoes. The hives are kept on packing boxes with a sweet water solution to supply the intellectual nourishment for the bumblebees.The bees pose no threat to people forming in the hydroponic green house.

4.13 Hive of bumblebees.

For the pollination process bumblebees have been used in the green house. The procedure has been explained below:

Step 1

Purchase a hive of bumblebees. The box shown in fig 4.5 contains bumbles bees which can be placed at suitable location in the hydroponic greenhouse.

Figure 4.5: Hive of Bumblebees for pollination

Step 2

Placed the beesô box in the glasshouse. Close all ventilation in the greenhouse before open the box.

Step 3

Maintained the bumblebeesuitable atmosphere. Bees are happy and more productive in the temperatures between 59º F and 77º F. The use of chemical and pesticides is not recommended.

Step 4

Feed bees with sweet water solution having 2 parts of water and 3 parts of sugar in a specific shape bee feeder which is easily available in the market.

Step 5

Replaced the bumblebees when needed. It depends upon the area of green house and size of the beeôs box, the life span to keep the colony of bumblebees in door is 4 to 12 weeks. Due to the week pollinationthe fruit quality becomes effects. The process of Pollination mustbe occurred in the mid of the day when humidity level are 50-70% which are considered as most suitable.

4.14 Irrigation

Timely availability of water is very much needed for greenhouse production. The process of transpiration consumes more than 90% of the water,which used is for the irrigation nutritionto the plants, leaves, fruits and tokeep the plant cool. In the use of rock wool as substrate of the plant sufficient water and nutrient supply must ensure to the plant roots. This prevents the solute concentration in the rock wool. Due to this situation the more nutrient solution about 20% extra is normally supplied to the plants which recycled after drainage. Fig 4.6 shows the hydroponic control system which supply nutrient solution water to the plants through irrigation pipes. The automatic hydroponic controls systems are also available in the market which supplies the nutrient solution to the plants as per the input provided to the system. In Abbottabad hydroponic farm house manual system in installed for the supply of nutrient solution to wards the greenhouse.

Figure 4.6: Hydroponic irrigationControl system

4.15 Electric Conductivity

To measure the salinity level (total solute concentration) of the nutrient solution in the root, Electrical conductivity is very important. It effect on plant water relationship which is its major function. It effects on the availability of water. In case of high salinity level in the plant root the water intake decrease in the plant which consequently effect on the overall growth. Theconcentration of nutrient in the irrigation water is used to control the development of plant growth and quality of fruit which mainly depends upon the osmotic potential at the stem of plant.

4.16 PH:

The PH of tomato is normally 5.6-6.5 which considered good. If it increases or decrease the absorption of nutrients are not proper.

4.17 Harvesting

Harvesting is done when tomatoes are mature at red stage means that about 95% are red from the overall.It is noticed that on that point are some changes that tend to go red inside first, so always try and compare the various ripening stages.

There are 6 accepted colour Stages:

Phase 1: Green ï surface of the tomato is completely immature

Phase 2: Breakers ï a definite shift in colour from green to tan-yellow, pinkish or red on no more than 10% of the aero foil

Phase 3: Turning ï more than 10% but less than 30% of the surface, in the aggregate, shows change as in stage 2

Stage 4: Pink ï more than 30% but less than 60% of aggregate surface shows pink or red colour. The yellow tan colour is no longer visible

Stage 5: Light Red ï more than 60% of aggregate surface is reddish pink or red provided that not more than 90 % is red

Stage 6: Red ï more than 90% of surface in the aggregate show red colour and no pink is visible

Harvesting is done by the cutters. The tomato Cluster is harvested about 1 cm from the stem. Clusters are then put in harvesting boxes. These boxes are loaded at the harvesting cart which is transported to the packing area. The red ripe fruit is harvested for the direct market sale. Whereas in case of export to other countries or far distances within the country the fruit harvested at initial pink colour so that the thin skin of the fruit wall may not be damaged during packing and transportation. A lot of arrangements have been introduced to reduce the labour cost and protection of fruits during harvesting and packing. Harvesting system is tube rail system for picking carts along the rows. Beefsteak tomatoes harvest along with the calyx to ensure their freshness and to promote among customer in high marketôs value. The whole bunch cluster is cut off in cluster tomatoes at the main root and kept together rather to place in a layer ina packing box. Fig 4.7 shows the basket of ripen hydroponics tomatoes in Abbottabad hydroponics farm house. These are ready for sale in the market.

Figure 4.7: Ready Hydroponic Tomatoes

4.17.1 Marketing

Tomatoes are being sold in local market of Abbottabad. Tomatoes are being exported to Dubai, Bahrain, Saudi Arab, Doha, Abu Dhabi, and Musket.

4.18Environmental control

4.18.1Temperature

The temperature plays very important role in the propagation of hydroponics tomato. Hydroponic tomatoes are very responsive to temperature so temperature is regulated to an optimum level. The temperature requirement ranges from 25-28 degree Celsius. In summer this temperature is regulated by pad and fan cooling system. In winter heating system is available which maintains the temperature of this range.The table 4.4 shows the summery of these parameters maintained in the study

Table 4.4: Environmental control parameters

Temperature	25-28-degreecelsius
Relative humidity	60-70 %
Light	3000 joules /cm sq.
PH Value	6 - 9

4.18.2Carbon Dioxide

CO_2(carbon dioxide) is added into the greenhouse by many ways. The propane burner or Natural gas is used to generate carbon dioxide from hot water boiler by burning it through natural gas/propane. This CO_2 is then sending to green house where it ejects from the pipe.

4.18.3Relative Humidity

In summer the relative humidity is maintained 70-80%. In winter the relative humidity is maintained 60-70%. Diseases spread more rapidly under conditions of high relative humidity. Decreasing relative humidity include venting the humid air and replacing it with drier outside air. Powdery mildew and botrytis spreads due to high humidity.

4.18.4Light

Tomato plants require 3000 joules/cm sq. When light intensity is too high then shade cloths are used for the protection of fruit from direct sun heat and to keep the whole environment suitable for the plats the direct sun heat to the fruit can cause sunscald, russet ting, and cracks.

However, shade cloths also reduce plant transpiration, because stomata close, so leaf temperatures are not necessarily reduced as much as air temperatures by shade cloths**.**

4.19 Water shortage

In hydroponic system the growth of plant depends upon the quantity of water, quality of water and temperature of the closed environment. There are many factors which influence the growth of plant and are directly linked with the water quantity and surrounding temperature i.e. plant height, leaf length, flower truss, head thickness, number of leaves, and fruiting truss. In case of water shortage during the weekly cycle all the factors get disturbed effect the plant yield which consequently effects on the overall production of the shed.
According to theobservation made at Abbottabad hydroponics farm house the average daily growth is 3.11 cm (1.22 inches per day). Average growth becomes decrease due to water shortage in high temperature and, if the quality of water is very low with high pH and high Electrical conductivity. As the temperature high,the water availability becomes low and plant growth tends slow.

4.20 Clipping of tomato

This is the process of tying the stem of plant with rope with the help of clip. Clipping is done to support and direct the plant in a particular direction. Clip attach to rope which is hanging. This rope is attached to a wire which is tied to walls horizontally.

4.21 Lowering of tomato plants

Lowering is done for maintenance of plant length to a proper height. The main purpose is protection of plant head from burning as at upper side temperature is high. Another purpose is to clip the plant as when the plant crosses the support wire then it cannot be clipped. Another purpose of this is to save plant from direct sun light. Due to direct sun light flower may dropand head may burn. When the plants cross the support wire then there is no place to climb upward so their head turn downward.

4.22 De-leafing of plants

De-leafing is done for the removal of older leaves, sick leaves and damaged leaves. How much leaves should be removed depends upon the season. In summer larger number of leaves is kept at the plant to provide shade to fruit to increase its ripening time. In winter small numbers of leaves up to 10 leaves are kept at plant to provide sun light to the fruit for ripening as intensity of light is low in winter. By removing older leaves fertilizer wastage is decreased. Fertilizer goes to younger leaves and fruits.

4.23 Twisting of plant

Curling the stem of plant around rope is called twisting. Twisting is done for giving support to the plant to climb upward. In this way plant uses the vertical space. By clipping plant is kept attached with rope.

4.24 Removal of extra shoot

This is done to remove the extra shoots having goal, increase the quality, shape and size of the fruit. This problem of side shoot is, it extracts the food as this is new plant. Due to this plant growth slows down because most of the food goes to the new plant and also fruit size doesnât increase.

4.25 Water Usage for hydroponic system from Abbottabad Hydroponic Farm

Green house size = 2950±100 sqm.

No of plants in green house = 7500 plants

First Water	=	1 liter/plant (one-time watering)
Blossom Stage water	=	200-300 ml/day/plant (for 45 days)
Fruiting stage	=	300 ml/plant (for15 days)
Harvesting stage	=	300 ml/ plant (For 30 days)

4.26 Water Usage for Geoponic system from Abbottabad Farm

From sowing to harvesting water required/plant	=	400 mm to 600 mm/plant
Geoponic data season	=	winter
Sowing time	=	30 Nov to 14 Dec
Total crop period	=	14 - 16 week.
Land preparation time	=	10 - 15 days
Total number of irrigation required	=	16 Noôs of irrigation
Frequency of irrigation	=	1 Irrigation/week.

CHAPTER 5

RESULTS AND ANALYSIS

5.1 Results

The objective of this comparative study is to see the water usage requirements whether or not hydroponically produced tomatoes are manageable and suitable alternatives to geoponically produced tomatoes in Pakistan. As per the results presented, the hydroponic production of tomato uses water more efficiently and gives high yield of production in a controlled environment. This higher yield of hydroponic production is due to the whole year production in the closed and controlled environment in the hydroponic greenhouse system. Due to the controlled environmentôs circumstances, the days required to complete the harvesting cycle can be reduced which allows continuous production of the crop throughout the year. The use of hydroponic production is not limited to tomato only and it will vary considering the operational procedure of the crop under which it is grown. The water volume of consumption for a plant in both the systems, geoponic and hydroponicisvery much different however,the delivery of wateris more efficient in the case of hydroponic system (Jensen et.al 2014).

Hydroponic system is evolutionover the production of geoponic system, which uses more land and water on a yield basis and requires arable land. Eliminating the need for arable land has other benefits including versatility in system siting and a potential reduction in the distance in which food must travel. Performing a life cycle assessment that considers the environmental impact of food transportation could show whether this benefit of hydroponics is significant.

5.2 Production

The production yield of hydroponic tomato in a unit of per acre has been found 8.35 ± 0.15 times more than geoponic production in Pakistan. Specifically, hydroponic tomato production has been calculatedwith a result in yield of 12.28 ± 0.42 kg/m^2/crop (± = SD, standard deviation) while the productionof tomato by geoponic methods is projected to yield 1.04 ± 0.06 kg/m^2/crop (Figure 5.1).

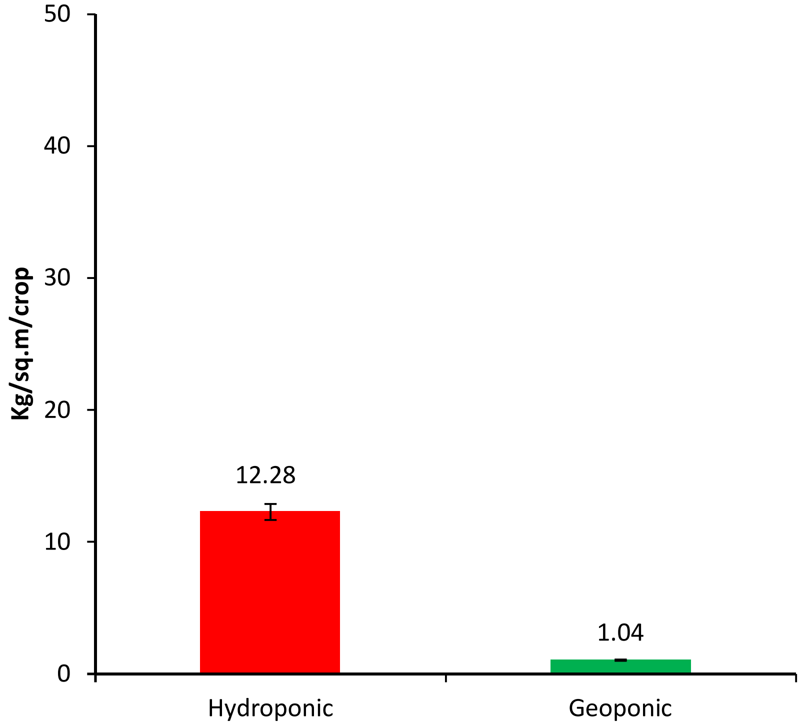

Figure 5.1. Yield of tomato in kilograms per square meter grown by hydroponic verses geoponic methods.

5.3 Water Demand

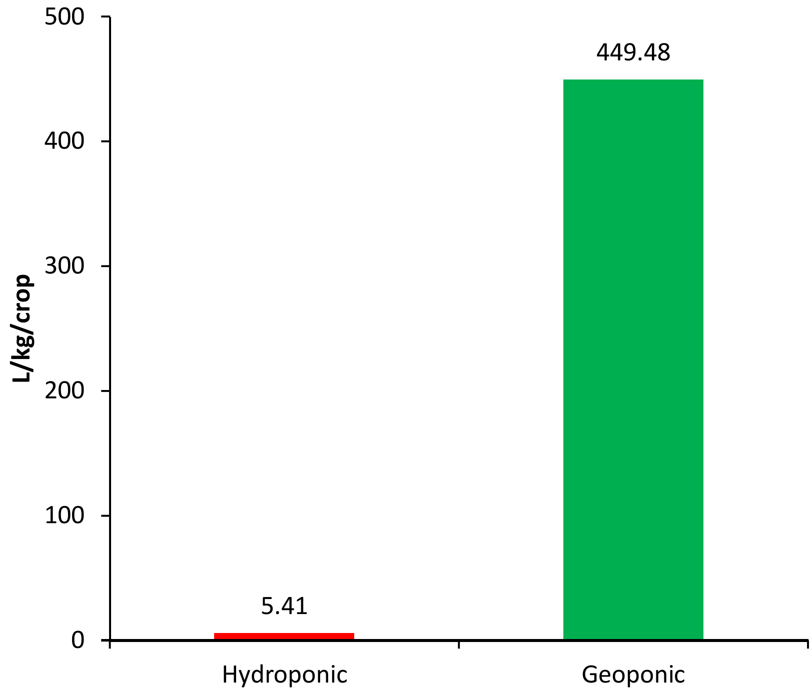

Figure 5.2: Water use for tomato in litters per kilogramfor hydroponic verses geoponic system

The consumption of water for the production of tomato in the case of hydroponicsystem and geoponic system in Pakistan has been compared on specific area basis and whenit is compared in terms ofyield, it becomes 83.08 ± 8.25 times lesser water demanding in hydroponic system as compared to geoponic system. The production of hydroponic tomato has an estimated water demand of 5.41 ± 0.55 L/kg/crop specifically, whereas geoponical tomato production has an estimated water demand of 449.48± 89.89 L/kg/crop as shown in Figure 5.2.

The comparison of boththe, hydroponic and geoponic system in terms of yield and water use along with standard deviation is expressed in table 5.1 which shows the results that in geoponic system the yield of tomatolower with higher water demand where as in hydroponic system the yield is higher with low water demand.

5.4 Time Comparison

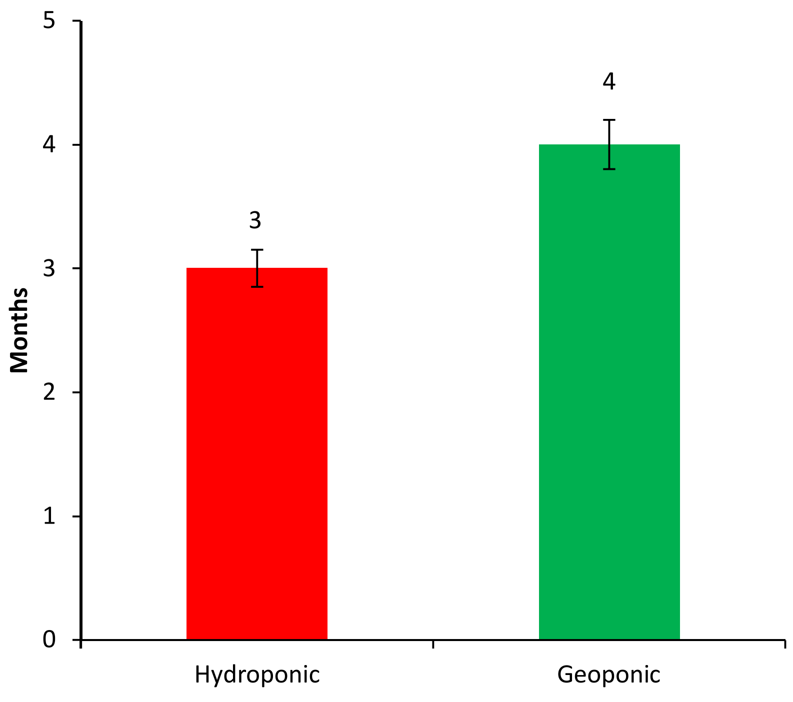

Figure 5.3: Time period for single crop of tomato for hydroponic verses geoponic system

Comparison of the growing time for both the system has also been made. The single crop growing time for hydroponic system is 3 months where as in geoponic system it is 4 months as shown in Fig 5.3. As a matter of fact, 4 numbers of crops can be grown in a year considering the hydroponic system where as 3number of crops for Geoponic system

Table 5.1. Summary of crop datamodeled with standard

	Yield (kg/sqm/crop)		Water Use (L/kg/crop)	
Method	Value	S.D.	Value	S.D.
Geoponic	*1.04*	*0.06*	*449.48*	*89.89*
Hydroponics	*12.28*	*0.42*	*5.41*	*0.55*

5.5 ANALYSIS

5.5.1 General

To take the estimation for the geoponic production of tomato the study presumed that only single crop of tomato in a given yearhas been considered. While it may be true, that some of the land are applied to grow tomato is fixed forthe crops of summer seasons, wherethere are no production of tomatoes.It might be thatthose crops require different energy and water needs than tomatoes. Hydroponic greenhouses come in different shapes and can be constructed almost anywhere. It would be more recommended to make different speculative greenhouses. With changing surrounding assumptions, the speculative greenhouses could produce differentsolutions. In summation, the surveyconducted for direct water inputs to hydroponic and geoponic tomato production did not consider the energy consumed for the case of hydroponic and geoponic systems.

Doing the assessment on a complete life cycle of geoponic verseshydroponic tomato, production could also create different outcomes, with labour hours likely figuring well-known in the economic calculations. In the last,this comparative study has not scrutinizedthe additional elements that might hamper the successful execution of hydroponics system, such as energy insufficiency and higher advanced capital costs

5.5.2 <u>Hydroponic Research Data of Water Usage and Yield</u>

The research on hydroponic system carriedout for winter season starting from November 2016 to February 2017 in Abbottabad hydroponic farm, having size of 220 ft length and 146 ft width. The total no of plants grown in green house are 7500.First watering was applied on November 02, after transplant from nursery to gutter. Fig 5.5 shows the plant which is taken from the nursery and ready to transplant in to growing gutter.

Fig 5.4: Plant ready for transplant to growing gutter

5.5.2.1 First Watering

First watering having quantity of water 1 liter / plant which is only one time watering after transplant from nursery to growing gutter is supplied. The commutative water quantity becomes 7,500 liters for stage 1.

5.5.2.2 Blossom Stage

Thereafter 200-300 ml of water supplied to each plant in day up till the blossom stage which is around 45 days after transplantation having commutative water quantity (1,500 liters/day to 2,250 liters/day) or 67,500 liters to 101,250 liters for complete stage 2.

5.5.2.3 Fruiting Stage

After the completion of stage 2 and passing 45 days from transplantation to blossom stage, the next phase comes which is called fruiting stage. Time duration for fruiting stage is 15 days after completion of blossom stage. The water quantity of 300ml/ plant/day has been supplied for 15 days having cumulative water quantity of 2250 liter /day or 33750 liters for 15 days. Fig 5.4 shows fruit is hanging on the plants at the completion of fruiting stage.

Fig. 5.5: Fruiting Stage in hydroponic farm

5.5.2.4 Harvesting Stage

A water quantity of 300ml/plant has been supplied to the plant till the harvesting stage which is 30 days after the completion of fruiting stage. The cumulative water quantity for harvesting stage is 2250liter/day or 67,500 liters for the whole period of 30 days. Fig 5.5 shows the tomato crop which is ready to harvest. The water cycle starting from first watering till the harvesting stage complete with total quantity of 13500 liter/day to 14250liter/day for a plant and 176250liter to 210000 liter for 7500 plants in the greenhouse shed.

Fig 5.6: Harvesting Stage

The overall requirement of water for 7500 plant in Abbottabad hydroponic farm house has been worked out, which is 23.5 liter /plant /crop to 28 liter/plant/crop. The yield of tomato produced is 35 ton/crop to 37.5ton/crop, whereas on average it comes out 36.25 ton/crop. Moreover on area basis it comes out 11.76kg/sqm/crop to 12.71 kg/sqm/crop.

Thewater demand has been worked out by taking the average of production i.e.36.25ton /crop is 4.86liter/kg/crop to 5.97liter/kg/crop.

5.5.2.5 Findings

By taking the average of yield and water demand from the results of hydroponic production the tomato yield is 12.28 $\pm$ 0.42 kg/sqm/crop with water demand of 5.41 $\pm$ 0.55 liters/kg/crop

5.5.3 Geoponic Research Data of Water Usage and Yield

The research on geoponic system carriedout for winter season starting from November 30, 2016 to March 01, 2017 in the surrounding of Abbottabad region.The study area selected for the geoponic production system was in acre having 4046.86 sqm with total noȏs of plants of 10000. The area and plant then rationalize with the hydroponic plant areas and plants noȏs for the most appropriate comparison of both the systems. Fig 5.6 shows the area selected for the water comparison for tomato crop. The land shows irrigation pattern in tomato field.

Fig 5.7: Irrigation in Geoponic tomato fields

5.5.3.1 Delta of water for geoponic tomato crop

The requirement of water for geoponic tomato crop from first watering to harvesting is 400mm to 600mm/plant (16 to 20 inch). The water requirement increases with the increase of temperature of the area. Total crop period for tomato crop is 14 to 16 weeks. The land preparation time is around 10 to 15 days. Total 16 nos of irrigations with a frequency of 1 (one) irrigation / week is required for the tomato crop.

5.5.3.2 Water demand for Geoponic system

By taking the water requirement 400mm to 600mm/ plant from sowing to harvesting on the rationalized area of 3035.19 sqm the water demand has been calculated which come 1213616.01liter / crop to 1820432 liters /crop having a period of 16 weeks.
Fig 5.7 shows the tomato plant in the field after 7th week of watering

Fig 5.8: Geoponic tomato crop in field

5.5.3.3 Production in Geoponic system

The output of tomato in the studied area has been computed and compared with the data of Pakistan Agriculture Research Council. The yield of tomato per acre in geoponic system is 4 tons to 4.5 tons (4000 kg to 4500 kg/acre). After rationalizing the area and nos of plant the production of tomato for a crop tends to 3ton to 3.375ton /crop.The overall requirement of water and production of tomato in geoponic system has been worked out, which is 359.58 liter /kg /crop to 539.37 liter/kg/crop. The yield of tomato produced is 0.98kg/sqm/crop to 1.11kg/sqm/crop, whereas on the average, water demand comes out 449.48 $\pm$ 89.89 liter/kg/crop and yield of tomato is 1.045 $\pm$0.065kg/sqm/crop. Fig 5.8 shows the tomato ready to harvest from the geoponic field

Fig 5.9: Ripe tomato in geoponic field

5.5.4 Findings

By taking the average of yield and water demand from the results of hydroponic and geoponic production the difference of yield is 11.80 $\pm$ 0.26 kg/sqm/crop (Times more hydroponic yield) whereas 83.08 $\pm$ 8.25 liter/kg/crop (Times Less water required in hydroponic system) The calculation data sheets of hydroponic system and geoponic system are attached as Annexure A.

CHAPTER 6

CONCLUSION & RECOMMENDATIONS

6.1 Conclusion

In spite of the high requirement of energy, hydroponic system is anencouraging technology. The increase of water use efficiency in crop output is a clear need in areas with confined admittance to this resource.Many elements impact the viability of hydroponic system of crops production. Availability of more advancedregulating devices can decreases the cost to keep the contained environment in hydroponic systemof greenhouses. The accessibility of land, food, and water in future will affect the viability due to increase in need.Hydroponics is the technology which is more water efficient, time saving and turns over the yield of production a lot more.The land used by hydroponic system is a good deal less as compared to geoponic system, which can further be used for many other purposed like trees and wildlife.Food can be transported all over the globe to places where agriculture is hard or impossible or where certain foods cannot be developed due to shorter growing seasons and water scarce area. By using hydroponics, these foods can be grown locally. Referable to the fact that growing indoors and doing away with soil, which contains bacteria and many common insects, thereȃs no demand for toxic pesticides to protect crops.The system which is more water efficient like, hydroponic will be more appealing to city planners in case of land and water scarcity. Administrative authority and local support will also strengthen the perspective of hydroponic system when subsidies and investments will be provided against the initial cost of hydroponic infrastructure system.

6.2 Benefit of the study

Hydroponically produced tomatoes use water more productive than geoponical farming and offers throughout the year production. Moreover, the waste water from gutter system can be reused in case of hydroponic system.

A hydroponic watering system has beneficial impact for growing plants near sensitive water resources. The arrangement provides for efficient usage of water and nutrients, and minimise contaminant percolation losses to the environment that are very common with purposefully grown plants. Sensitive water resources include public drinking water source areas, the margins of waterways and estuaries and areas within the catchments of conservation valued wetlands.

This can be anapproach to reinforce the feeding system of worldôs rising population.

Hydroponic systems having artificial plant growing media watered with a controlled nutrient solutionwhich poses a low contamination risk to sensitive water resources and prevent the environment and facilities.In most of the areas, excluding land subject to flooding, these systems should be environmentally acceptable provided effective measures deal with plant wastes and use of hydroponic waters.

The waste water is full of nutrients which can be used on any land to make the soil fertile and to keep the environment green.

6.3 Future Recommendations

The following are recommendations for future studies:

- Comparison of land used for the hydroponic and geoponic system.
- Comparison of energy consumed for the hydroponic and geoponic system
- Re-usage of nutrient water after complying the requirements in Hydroponic System

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Annexure A

Hydroponic Research Data of Water Usage for season Winter Nov 2016 to Feb 2017 from Abbottabad Hydroponic Farm

Hydroponic system

(Green house size) = 220x146 =32100 Sft=2985.13sqm = 2950±100 sqm.

No of plants in green house = 7500 plants

Research carried out in winter season crop and its water usage.

a. First watering (after transplant from nursery) on November 02,2016

First Water	=	1 liter/plant (one time watering)
1*7500	=	7500
Cumulative water (1)	=	7500 liters

b. Till Blossom Stage (December 16,2016)

Blossom Stage	=	200-300 ml/day/plant (for 45 days)
200*7500*45/1000	=	67500 liter
300*7500*45/1000	=	101250 liter
Cumulative water (2)	=	67500 liter to 101250 liter
	=	Or 1500 liter to 2250 liter/day (for 45 days)

c. Till Fruiting Stage

Fruiting stage	=	300 ml/plant (for15 days)
300*7500*15/1000	=	33750 liter
Cumulative water (3)	=	33750 liter
	=	or 2250 liter/day (for 15 days)

d. Till Harvesting Stage

Harvesting stage	=	300 ml/ plant (For 30 days)
300*7500*30/1000	=	67500 liter
	=	or 2250 liter/day (for 30Days)
Cumulative water (4)	=	67500 liters

e. Total water /day for 7500 plants from transplantation to harvesting

With 200ml at 2nd stage = 7500 + 1500+ 2250 + 2250 = 13500 liter

With 300ml at 2nd stage = 7500+2250 +2250 +2250 = 14250 liter

= 13500 liter to 14250 liter / day.

f. Total water / crop for 7500 plants from transplantation to harvesting

= Cum. water (1) + Cum. water (2) + Cum. water (3) + Cum. water (4)

With 200ml = 7500 + 67500 + 33750 + 67500 = 176250 liter

With 300 ml = 7500 + 101250 +33750 +67500 = 210000 liter

= 176250 lit/crop to 210000 liter/crop

g. Water requirement /plant/ crop

Water requirement / plant /crop = $\frac{176250}{7500}$ to $\frac{210000}{7500}$

= 23.5 liter/plant/crop to 28 liter/plant/crop

h. Production in Hydroponic system

Yield of tomato As per Abbottabad hydroponic farm is 35 ton to 37.5 ton /crop on 2950 sq.m area i.e.

Production of tomato in hydroponic System = 35 to 37.5 ton/crop

= 35000 to 37500 kg/crop

Yield of tomato/kg/sqm/crop = $\frac{35000}{2950}$ to $\frac{37500}{2950}$

= 11.86 kg/sq.m/crop to 12.71 kg/sq.m/crop

i. Water demand of crop

As the yield of tomato in Abbottabad hydroponic farm is 35 ton to 37.5 ton, by taking the average of production 36.25 ton , water demand has been worked out as:-

Water demand /kg/crop = $\frac{176250 \text{ lit}}{36250 \text{ ton}}$ ± $\frac{210000 \text{ lit}}{36250 \text{ ton}}$

= 4.86 liter/kg/crop to 5.97 liter/kg/crop

j. Results/ Conclusions

Results

(i) Yield: - Avg.	=	11.86 +12.71/2 = 12.28 ,
Yield of tomato	=	12.28 ± 0.42 kg/sqm/crop
(ii) Water:- Avg	=	4.86 +5.97/2 = 5.41
Water demand	=	5.41 ± 0.55 liter/kg/crop

Conclusions

Yield of Tomato	=	**12.28 ± 0.42 kg/sqm/crop**
Water Demand	=	**5.41 ± 0.55 liter/kg/crop**

Geoponic Data of Abbottabad surrounding area for Water Usage from (Nov 30, 2016 to 01March 2017)

General Data

1 cusecs discharge is required to irrigate 1 acre field in 2 hours. The water requirement increases with increase in temperature of the area

a. Delta of water for geoponic tomato crop

From sowing to harvesting water required/plant	=	400 mm to 600 mm/plant
Geoponic data season	=	winter
Sowing time	=	30 Nov to 14 Dec
Total crop period	=	14 - 16 week.
Land preparation time	=	10 - 15 days
Total number of irrigation required	=	16 Noꞔs of irrigation
Frequency of irrigation	=	1 Irrigation/week.
Area for geoponic research	=	1 acre = 4046.86 sqm
Number of plants in 1 acre	=	10000 plants.

Geoponic field area has been rationalized with the area and no of plants in the Abbottabad hydroponic farm for most appropriate comparison.

1 acre land area	=	4046.86 sqm
No of Plants per Acre	=	10000 plants
10000 *3/4	=	7500 plants
4046.86 *3/4	=	3035.19 sqm
Total water from 1st watering to harvesting Weeks)	=	16-20 inches (for 16
	=	or 0.4 to 0.6 m

b. Water demand for geoponic

For Area 3035.19 sqm	=	3035.19*0.4 to 3035.19*0.60
	=	1214.07m3/ crop to 1821.11 m3/crop
	=	42868.81 cft/crop to 64303.5cft/crop
1cft = 28.31 liters	=	1213616.01lit/crop to 1820432.08lit/crop (for 16 Weeks)

c. Production in geoponic system

As per the field data and available data from Pakistan agriculture research council the production of tomato / acre is 4 to 4.5 tons. By taking the above said data the calculation has been done.

Average production in geoponic system	=	4 to 4.5 tons
	=	4000kg/ acre to 4500 kg/acre/ crop
By rationalization of data for 3035.19sqm area and 7500 plants	=	3 to 3.375 ton / crop
	=	or 3000 to 3375 Kg/crop

d. Yield of tomato

Yield of tomato/ sqm / crop = 3000/3035.19 to 3375/3035.19

= 0.98 kg/ sqm/crop to 1.11kg/sqm/crop

e. Water demand in geoponic system

By taking average of 3.0 ton and 3.375 ton production = 3187 kg (prod)

Water demand = $\frac{1213616.0 \text{ Lit}}{3187 \text{ Ton}}$ to $\frac{1820432.08 \text{ Lit}}{3187 \text{ ton}}$

= 359.58 liter/kg/crop to 539.37 liter/kg/crop

f. Results/ Conclusions

Results

Yield Avg. = 0.98+ 1.11/2 = 1.045

Yield of tomato = 1.045 ± 0.065 kg/sqm/crop

Water demand = 359.58 + 539.37 /2= 449.47

= 449.48 ± 89.89 liter/kg/crop

Conclusions

Yield of Tomato = 1.04 ± 0.06 kg/sqm/crop

Water Demand = 449.48 ± 89.89 liter/kg/crop

<u>Over all Conclusion of hydroponic and geoponic system</u>

(1) Hydroponic Yield = 12.28 ± 0.42 kg/sqm/crop

Water Demand = 5.41 ± 0.55 liter/kg/crop

(2) Geoponic Yield = 1.04 ± 0.06 kg/sqm/crop

Water Demand = 449.48 ± 89.89 liter/kg/crop

Yield difference = 12.28 /1.04 = 11.80 Times

(+) Value 12.70/1.10 = 11.54 Times

= (-) Value 11.86/0.98 = 12.10 Times

Difference = 11.80 ± 0.26kg/sqm/crop

(Times more hydroponic yield)

Water demand difference = 449.48/5.41 = 83.08 lit/kg/crop to

= 539.37/5.96 = 90.49 lit/kg/crop

= 83.08 + 8.25 liter/kg/ crop

(Times Less water in hydroponic system).